

CHAPTER 1

INTRODUCTION

1.1 HISTORICAL BACKGROUND

The Navy began using high frequencies for radio communications at about the time of World War I when a few communication systems were operated on frequencies near 3 MHz. In view of the extensive present-day use of high frequencies for long distance communications, it seems curious now that those Navy systems were intended for very short-range communications on the order of a few miles. The general belief at the time was that frequencies above 1.5 MHz were useless for communication purposes. Consequently, it was left to the amateurs to demonstrate that high frequencies were suitable for long-distance communications and to thereby expose the great potentialities of the high-frequency (HF) spectrum.

In spite of some difficulties posed by the propagating medium, the technical simplicity and low cost of HF systems relative to low- and mid-frequency communication systems led to rapid exploitation of the HF band. In this band, ionospheric refraction makes long-distance communication possible with considerably less power and much cheaper antenna systems than are required in the LF and MF bands.

1.2 PROPAGATION DIFFICULTIES

One of the salient features of high-frequency long-distance communication is the variable nature of the propagation medium. Successful transmission of HF signals over long distances is dependent upon refraction (apparent reflection) of radio waves by layers of the ionosphere. The height and density of these layers, formed primarily by ultra-violet radiation from the sun, vary significantly with the time of day, season of the year, and the eleven-year cycle (approximately) of sunspot activity. Because of these variations, it is generally necessary to use more than a single frequency, sometimes up to four or five, to maintain communications on a circuit.

Changes in the characteristics of the ionosphere during the eleven-year solar cycle cause a variation of approximately 2:1 in the portion of the HF band usable for long-distance communication. During periods of high solar activity the entire HF spectrum is usable, but during periods of low solar activity only the lower portion up to approximately 15 MHz can be relied upon for long-distance communication by ionospheric refraction.

At relatively short distances within approximately 300 miles of a transmitter, high-frequency communication becomes difficult because the minimum range for sky-wave propagation is beyond the receiving point while the signal strength of a ground wave may be inadequate for suitable quality reception.

HF radio circuits are prone to fading, and, in particular, to a selective type of fading which results from multiple reflections from the ionosphere, or multipath transmission. They are subject also to interference from atmospheric disturbances and other natural causes, and to interruption from magnetic storms caused by solar flares.

Because high frequencies can be used effectively with relatively low power for long-distance communications, the range of potential interference between stations is also large, and the number of stations that can use the same frequency without mutual interference is limited.

As a result of many years of intensive study, these disturbing effects are now understood well enough so that HF communications can be conducted with a high degree of reliability under all but the most extreme ionospheric conditions.

1.3 SPECTRUM CONGESTION

In spite of the difficulties encountered with HF propagation, the economic and technical advantages of using high frequencies have led to rapid expansion of the use of the HF band. Ultimately, as the number of users increased, use of the HF spectrum approached saturation. In 1950 President Truman cited crowding of the HF band as being the most pressing communication problem of the times. In 1964 the Joint Technical Advisory Committee of the IEEE and the Electronic Industries Association suggested that this band appears to be heading toward chaos as world requirements are expected to continue to exceed, at an increasing rate, the limited supply of usable frequencies. (ref. 1)

The HF band is shared by many users, both foreign and domestic, and only portions scattered throughout the band are allocated to the military services. In common with other agencies, Navy requirements have grown so as to severely tax the capacity of the Navy's assigned portion of the HF spectrum. The use of single-sideband equipment and the application of independent sideband techniques have increased the capacity, but not enough to catch up with the demand. Some predict that satellite communication will eventually relieve congestion in the HF band and that, for some types of service, it will replace HF for long-distance communications. Nevertheless, it appears that the HF spectrum will continue to be in high demand for some time to come.

1.4 TYPICAL NAVY HF COMMUNICATION SYSTEMS

Naval communications within the HF band can be grouped into four general types of services: point-to-point, ship-to-shore, ground-to-air, and fleet broadcast. Some of these services involve ships and aircraft which present special problems because of their physical characteristics and mobility. Generally, the less than optimum HF performance of these mobile terminals is at least partially offset by powerful transmitters and sensitive receiving systems at the shore terminals.

1.4.1 Point-to-Point Communications

Point-to-point systems are those established to communicate over long-distance trunks or links between fixed terminals. Generally, sufficient real estate is acquired at the terminals to permit the use of large, high-gain antennas aimed at opposite terminals of each link. This increases the effective radiated power and the sensitivity of the receiving system, and it also reduces susceptibility of a circuit to interference. With the path length and direction fixed, accommodation of the other propagation variables is simplified and highly reliable communications can be achieved.

Within the Defense Communications System (DCS), the standard bandwidth, 12 kHz, for each operating frequency is divided into four 3-kHz channels so that each channel can contain information different from the others. One is generally used as a voice frequency carrier telegraph channel (VFCT) which can accommodate sixteen teletype circuits. The others can be used for facsimile, voice, orderwire or other forms of data transmission. Navy point-to-point circuits that do not interface with the DCS are not constrained to the DCS standard bandwidth and channel alignment. Therefore, the bandwidths indicated in the emission designations given in JANAP 195 are used for these Navy circuits. (A table of these emission designators is included in NAVELEX 0101, 102 and a more detailed discussion is contained in ref. 21.)

1.4.2 Ship-to-Shore Communications

This application of the HF band is more difficult than the point-to-point case since one terminal, the ship, is mobile. In this case the path length and direction are variable. At the ship terminal the limited space and other restrictions prohibit installation of large, efficient HF antennas, and, because of the mobility of ships, shipboard antennas are designed to be as nearly omnidirectional as possible.

The constraints are not as severe at the shore terminal where there is sufficient space for more efficient omnidirectional antennas or arrays designed for area coverage. Moreover, at the shore terminal, a rotatable, high-gain antenna, or one of the fixed point-to-point antennas may be used under appropriate circumstances. For example, a rhombic antenna may serve admirably for long-haul ship-to-shore communications when the ship is at a distance such that its operating area is within the coverage of the antenna at that distance.

Several frequencies are usually assigned for each circuit so that the best frequency can be chosen for the propagation path conditions between the shore terminal and the ship's location. The length of the path, among other things, determines whether sky-wave or ground-wave propagation will be effective for the link. Ships relatively close to shore usually depend upon the ground wave for communication with the shore terminal. Alternatively, high-angle sky-wave propagation can be used for communications within the skip distance; however, the probability of ionospheric support at high angles is relatively low.

1.4.3 Ground-to-Air Communications

The application of HF radio to communications between the ground and airborne aircraft is similar to the ship-to-shore case except the aircraft terminal changes position much more rapidly than does a ship. Transmitter power and antenna restrictions imposed by the airframe design limit the effectiveness of the airborne HF radio terminal so that all major circuit improvements must be made by the application of suitable techniques at the ground terminal. For example, higher-powered transmitters, lower-noise receiving installations, and more efficient antennas can be used on the ground. HF antenna considerations for ground-to-air communications are discussed in NAVELEX 0101, 104 — "HF Radio Antenna Systems."

1.4.4 Fleet Broadcasts

As the name implies, this type of service involves broadcast area coverage from shore-based transmitters to ships at sea. Messages addressed to a ship in a designated broadcast area are delivered by various means to the appropriate fleet broadcast station where they are broadcast for pickup by the ships. To overcome the propagation difficulties discussed earlier, the same information is broadcast simultaneously on several frequencies. That is, most fleet broadcasts are frequency-diversity transmissions. This gives flexibility for the receiving terminal to choose the best frequency for the path conditions at the time.

1.5 PLANNING CRITERIA

Most Navy point-to-point circuits are included in the DCS and, therefore, must be designed to satisfy the requirements imposed by the Defense Communications Agency (DCA) which prescribes engineering standards for the point-to-point circuits of the DCS. Since the DCA standards apply principally to circuit quality requirements over which control can be exercised only within the terminals of a circuit, these standards are discussed in NAVELEX 0101, 102 — "Naval Communications Station Design." Other than to prescribe a signal-to-noise ratio of 32 dB (for all types of service) and to specify the use of certain sunspot numbers for making propagation predictions, the DCA standards do not state circuit quality standards for the propagation path.

The Navy's ship-to-shore, ground-to-air, and fleet broadcast applications of HF radio are not directly controlled by the DCA standards since these circuits are not a part of the DCS. The interface between these services and the DCS does, however, come under control of the DCA, as does any circuit entering the DCS.

Although some HF system components aboard a mobile terminal, such as a ship or aircraft, may be comparable in performance to those ashore, other limitations force acceptance of mobile terminal performance that often is marginal at best. For effective two-way communications between a shore terminal and a mobile terminal, both the transmitting and receiving systems ashore should be superior to those aboard ships and aircraft. Generally, overall circuit performance can be improved by installing efficient antennas at low-noise-level sites ashore.

1.5.1 Navy Planning Documentation

Of the three basic types of documents used by NAVELEX for planning and controlling shore station electronic installation work, two are applicable to the propagation aspects of communications station design. The Communications Operating Requirements (COR), promulgated by OPNAV, states the functional requirements in terms of circuits and pertinent characteristics of each circuit. A Base Electronic System Engineering Plan (BESEP), developed by NAVELEX, translates the operational requirements of the COR into a detailed technical plan for meeting those requirements. The third type of planning document, NAVELEX Standard Plans, is not applicable to the radio propagation requirements of a circuit. Instead, reliance must be placed on propagation predictions for the types and grades of service required.

1.5.2 HF Radio Propagation Analysis

To bound the content of this handbook, the approach has been taken that the reader will be involved only in those aspects of planning directly related to high-frequency radio propagation. It is assumed that others will be responsible for equipment selection and installation engineering at the terminals.

In most cases some form of feasibility determination has been made before the requirement for a high-frequency circuit is stated. Generally, experience alone is sufficient to establish whether an HF circuit is feasible for the type of communication service needed. So, rather than being overly concerned with determining the feasibility, the planner is interested primarily in achieving optimum long-term performance over the propagation path. Nevertheless, his work will either confirm the feasibility of the HF circuit or it will provide data concerning circuit limitations imposed by the propagation path.

The propagation aspects of HF radio circuit design involve (1) an estimate of long-term propagation conditions for a given path, (2) a determination of system characteristics (transmitter power, antenna design, etc.) necessary for reliable communications within a range of variable propagation conditions, and (3) the selection of terminal sites that favor HF radio transmission and reception. The bulk of this handbook is devoted to discussion of these three topics.

